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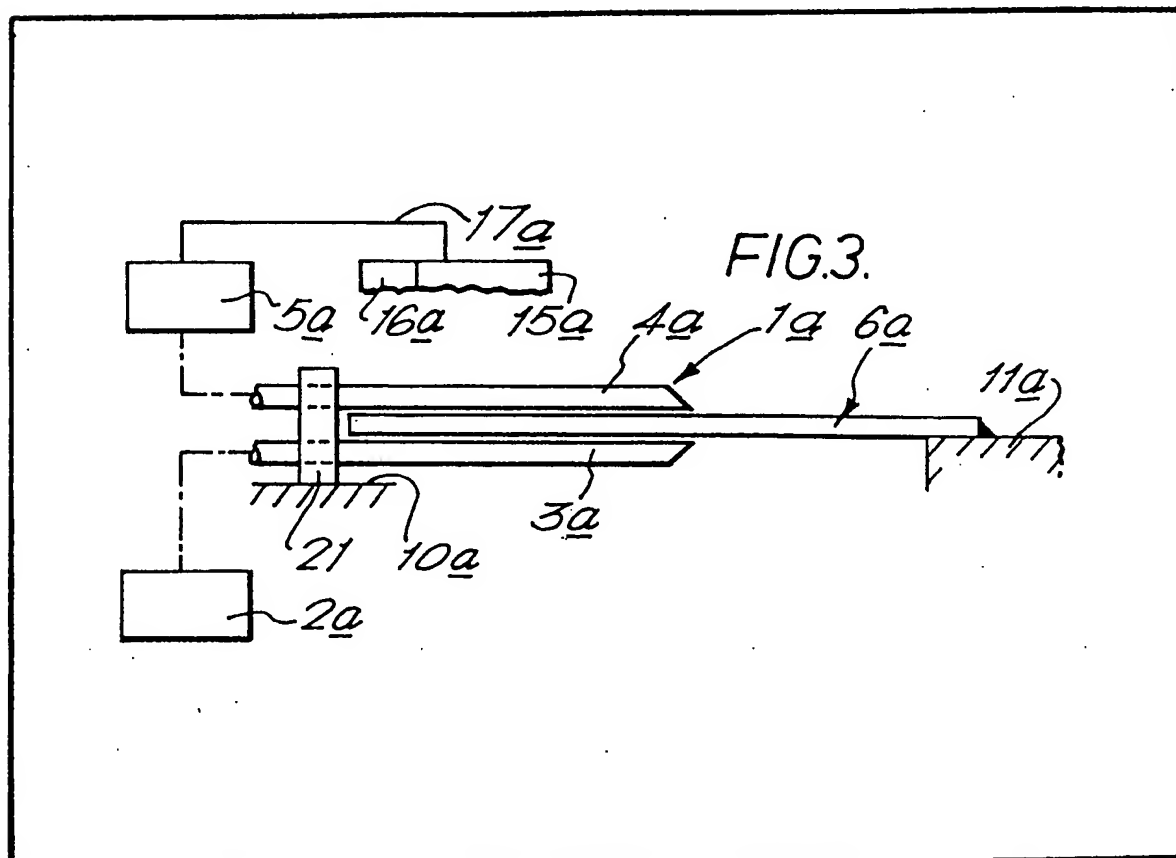
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 H3H
 (71) Applicant
 NMI Limited,
 (United Kingdom),
 Faggs Road,
 Feltham,

Middlesex,
 TW14 0LQ
 (72) Inventor
 Kenneth Frank Hale
 (74) Agent and/or address for
 service
 J. A. Boutland,
 8 Heatherstone Avenue,
 Hythe,
 Southampton,
 SO4 5LQ

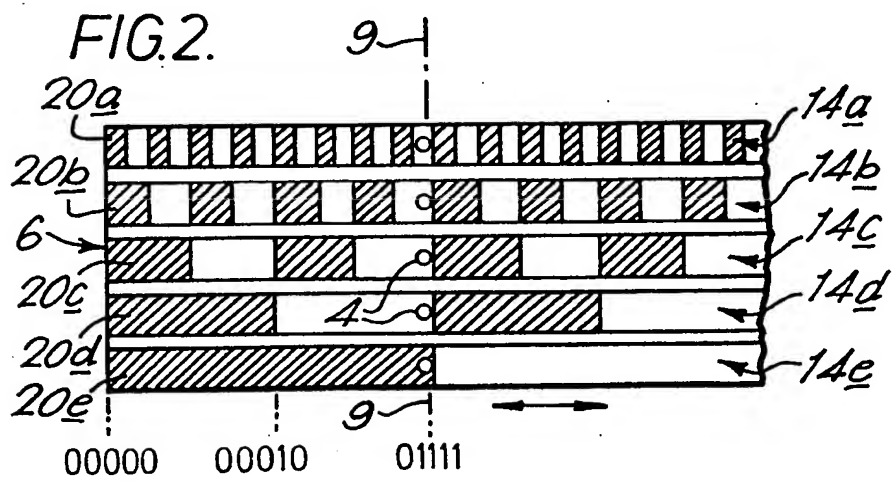
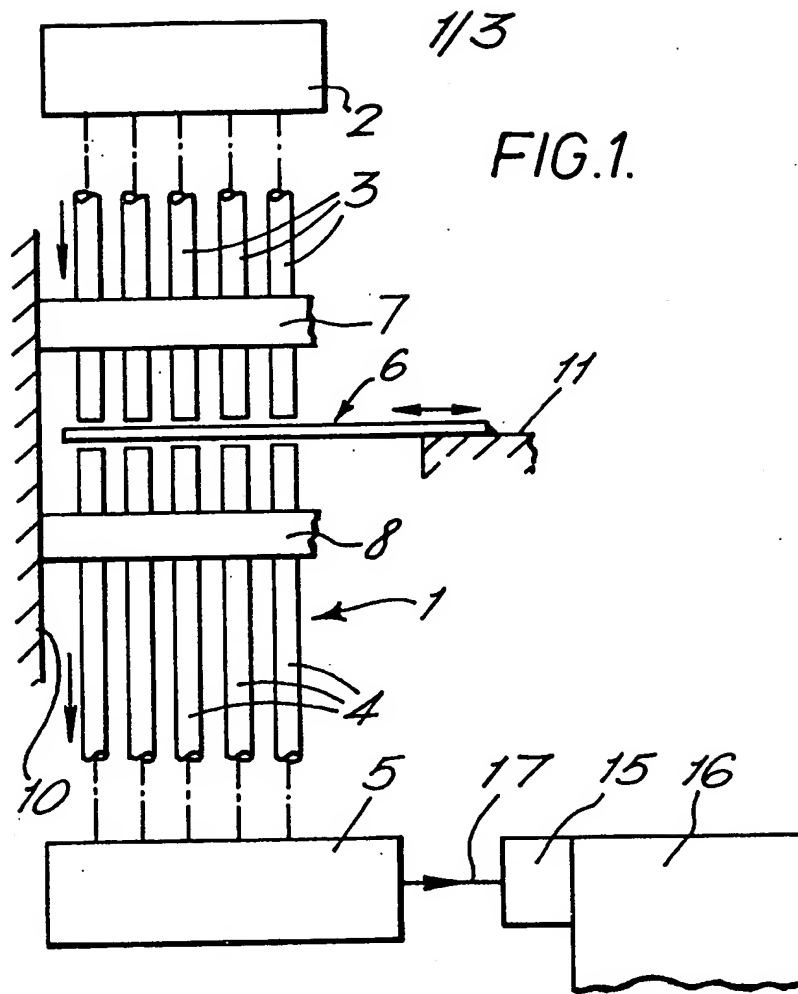
(54) Displacement measuring gauges

(57) A displacement measuring gauge
 1a comprises a light source 2a
 coupled to a plurality of fibre optic
 transmission paths 3a, and a plurality
 of fibre optic light receiving paths 4a
 Light paths 3a, 4a are disposed in

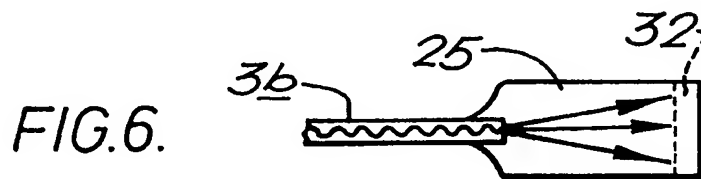
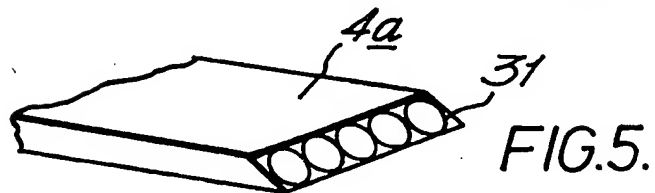
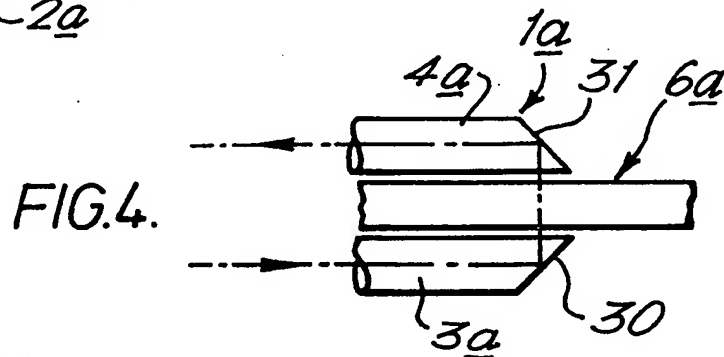
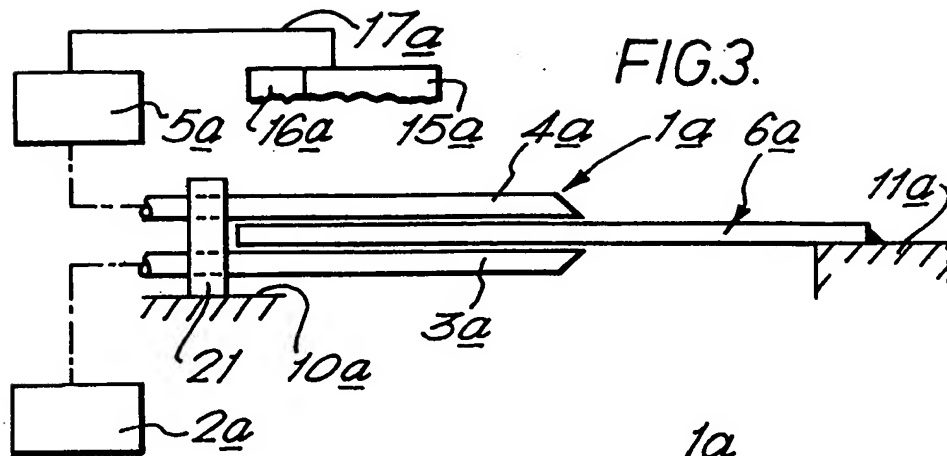
substantially parallel plane with
 encoder means 6a positioned
 therebetween. The encoder means 6a
 is movable relative to light passing
 from paths 3a to 4a so as to convert
 said light, whereby a measure of the
 relative displacement between a part
 11a secured to the encoder means 6a
 and a part 10a secured to the fibre
 optic paths 3a, 4a is given. The end
 face of the fibres are at 45° to their
 longitudinal axes. The encoder 6a may
 provide a Gray code. The output from
 the light receiving path 4a may pass
 to a memory 15a and computer 16a.
 In an alternative arrangement, the
 light receiving path is dispensed with
 and the encoder means made to
 reflect light signals back into the
 transmission path.



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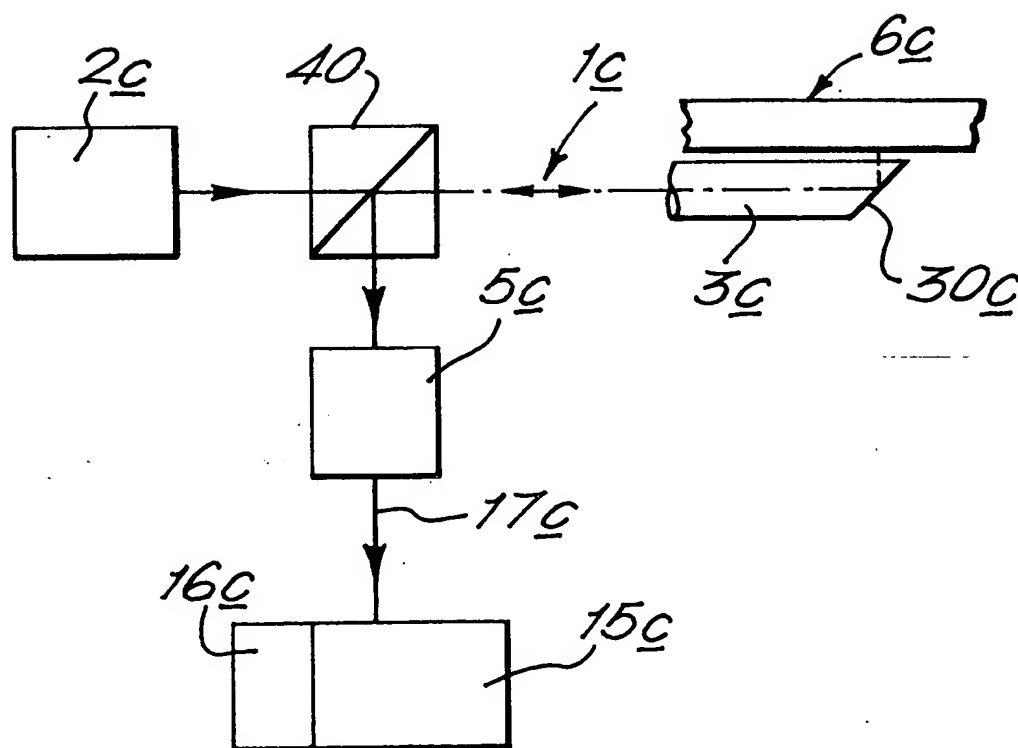


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FIG. 8.



SPECIFICATION

Improvements in or relating to displacement measuring gauges

Background of the invention

- 5 This invention relates to displacement measuring gauges.

Summary of the invention

- According to the invention, a displacement measuring gauge comprises light transmitting means, a plurality of fibre optic light receiving paths, and encoder means operable to convert light passing from the light transmitting means to the fibre optic light receiving paths, whereby relative movement between said light and said encoder means results in a conversion corresponding to displacement being measured.

- The light transmitting means may comprise a plurality of fibre optic paths disposed in substantial alignment with the fibre optic light receiving paths, the encoder means being disposed between the two paths.

- Alternatively, the light transmitting means may comprise at least one fibre optic path disposed substantially parallel to the light receiving paths, means being provided whereby light is reflected from the light transmitting path to the light receiving paths.

- The encoder means may make use of a Gray code.

- The light receiving paths may be operatively connected to a computer or microprocessor.

- The light receiving paths may be substantially parallel to the linear movement being measured.

- The end faces of the light receiving paths may be at substantially 45° to the linear movement.

- The light transmitting means may comprise a slab waveguide having an end face at substantially 45° to the linear movement.

Brief description of the drawings

- Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, wherein:—

- Figure 1 illustrates, in semi-diagrammatic form, one embodiment,

- Figure 2 illustrates the encoder means 6 of Figure 1,

- Figure 3 illustrates, in semi-diagrammatic form, a second embodiment,

- Figures 4 and 5 are details of part of Figure 3, Figures 6 and 7 are plan and side views of a modified fibre optic, and

- Figure 8 illustrates, in semi-diagrammatic form, a third embodiment.

- In the figures, like reference numerals refer to like components or features.

Detailed description of the preferred embodiments

- With reference to Figure 1, a displacement measuring gauge 1 comprises light transmitting means in the form of an optic source 2 coupled to a plurality of fibre optic light transmitting paths 3,

a plurality of fibre optic light receiving paths 4 (or light receivers) coupled to an optic detector 5, and encoder means 6 operable so as to convert light passing from the light transmitting means 2/3 to the fibre optic light receiving paths 4 such that relative linear movement between said light and said encoder means 6 results in a conversion corresponding to displacement being measured.

- The fibre optic paths 3, 4 are disposed in a common plane 9 (Figure 2) which is substantially parallel to the linear movement being measured. Thus the optic paths are disposed on opposite sides of the encoder means 6.

- The fibre optic paths 3 and 4 are secured, respectively, by clamps 7 and 8, to a member 10 and the encoder means 6 is secured to a member 11, wherein displacement of the member 11 relative to the member 10 is to be measured. (The members 10 and 11 may be portions of the same structure).

- The fibre optic paths 3, 4 each comprise (in this embodiment) a row of five fibres extending substantially normal to the plane in which the encoder means 6 is movable. The fibres of one row are in substantial axial alignment with but spaced from, the fibres of the other rows. The encoder means 6 is disposed in the gap between the adjacent ends of fibres 3, 4. The light executes a zig-zag path in the fibres.

- The fibres 3, 4 each comprise a central, light transmitting, core enclosed in cladding.

- The optical source 2 makes use of light-emitting diodes and the optical detector 5 makes use of photodiodes; one light-emitting diode for each fibre optic 3 and one photodiode for each fibre optic 4. The source could be a laser. Other forms of source and detector are possible.

- As shown in Figure 2, the encoder means 6 comprises an optical slide or shutter carrying five rows (14a to 14e) of spaced-apart markings 20a to 20e; one row respectively for each fibre optic path. The rows of markings 20a etc. form scales and extend substantially normal to the common plane (9) occupied by the fibres of the paths 3 and 4. The markings 20a etc. either allow or prevent the passage of light through the encoder means 6.

- The spacing between immediately adjacent markings 20a in row 14a is equivalent to the core diameter of a fibre. The spacings between markings 20b of row 14b are equivalent to two core diameters, and so on, from row to row.

- The actual number of optical fibres employed may vary. Thus:—

- The number of discrete locations of the encoder slide 6 is 2ⁿ where "n" is the number of scales/fibre. Thus 5 rows or scales=32 encoder positions and 6 scales=64 encoder positions. The encoder 6 could have a different number of scales, for example eight, the number of optical paths 3, 4 corresponding to this.

- The markings 20a etc. of the encoder means 6 convert light passing from path 3 to path 4; the extent of conversion sensed between one fibre optic of receive path 4 and another of that path

depending on the position of encoder means 6. The converted light signals provide digital readout.

In the example illustrated by Figure 2, the row of fibre optics 4 are in the sixteenth position (counting from left to right). The readouts consequently transmitted along the light receiving paths 4 are "01111".

The encoder means 6 as illustrated makes use of a Binary code, i.e. light is either transmitted through a particular scale or is not so transmitted. Alternatively a Gray code may be employed, that is to say, a code in which the binary representation of the numbers 0—9 are given in the following table:—

	Decimal	Gray	Decimal	Gray
	0	00000	5	00111
	1	00001	6	00101
	2	00011	7	00100
20	3	00010	8	01100
	4	00110	9	01101

This gives an absolute reading of position, compared for example with a fringe-counting interferometer instrument which measures the displacement since the instrument was switched on.

With reference to Figure 1 once again, the digital readouts received by the optical detector 5 are transmitted through a suitable electrical connection 17 to a memory store 15 of a computer 16 for subsequent recall. This enables displacement changes which occur during fatigue stressing of structures to be recorded.

Information obtained may be printed out, or be graphically represented, for example by way of a histogram, for subsequent analysis.

The gauge 1 has particular application in the monitoring of the structural integrity of a variety of structures such as off-shore oil and gas platforms, ships, aircraft, bridges and chemical plants.

With reference to Figures 3, 4 and 5, in the embodiment illustrated therein, the rows of fibres forming the paths 3a and 4a are disposed in planes substantially parallel to the plane occupied by the linearly movable encoder means 6a whereby the encoder means is disposed between the substantially parallel light paths. The fibres forming the paths 3a, 4a are supported in a common bracket 21.

The common ends 30, 31 of the fibres of paths 3a and 4a have 45° bevels, as shown. These ends 30, 31 are polished, set in epoxy resin and aluminised so as to reflect light through 90°, from paths 3a to paths 4a, as illustrated in Figure 4. The end faces 30, 31 are not only disposed at 45° to the longitudinal axes of the fibres of the paths 3a, 4a but also to the direction of relative linear movement between the encoder means 6 and the part 10a.

The "linear" encoder means 6, 6a may be replaced by rotatable encoder means whereby

angular displacement of the encoder means is measured.

With reference to Figures 6 and 7, a single fibre optic 3b may serve as a light transmitting means. As shown in these figures, the fibre 3b is formed with an enlarged, light-spreading, end 25 serving as a slab waveguide, the width of which is made to correspond to the combined width of the light receiving fibre optic paths 4.

The fibre optic 3b is formed by setting a fibre in a slab of epoxy resin, forming a bevel at 45° to the longitudinal axis of the waveguide, on the free end 32 of the slab, and aluminising and polishing said end.

Figure 8 illustrates a modification wherein a gauge 1c employs an encoder 6c having reflective markings.

The gauge 1c illustrated is a modification of the gauge 1a of Figures 3 and 4, although the principles of the modification are not restricted thereto.

In Figure 8, light path means 3c are provided for simultaneously transmitting and receiving light signals. Light source 2c transmits light to the path 3c, by way of a beam splitter 40. The signals are reflected on to the encoder means 6c by the polished bevel ends 30c and are reflected back to the light path means 3c.

The beam splitter 40 diverts the reflected light pulses to the light detector 5c.

The light path means 3c and the encoder means 6c are disposed in substantially parallel planes.

The light path means of the gauge 1c may comprise a plurality of fibre optic paths, the end faces thereof being disposed at 45° to their longitudinal axes, as in Figure 5. Alternatively, the light path means may comprise a slab waveguide of the form shown in Figures 6 and 7.

Gauges according to the invention have various applications; for example in sensing displacement produced by stress or strain, or in sensing relative movement between parts of machinery. The gauges can be used with robots or other means for controlling parts, e.g. the robotic control of aircraft to optimise fuel consumption. The gauges can be associated with computers or microprocessors for control of displacement and the collection and recordal of displacement or strain history, the light receiving paths then being operatively connected to the computers or microprocessors.

The resolution of a gauge, i.e. the incremental displacement necessary to cause a change of one digit in the digital readout, is defined by the core diameter of the multimode or monomode optical fibre used. Core diameters of multimode fibres may be 50 to 200 microns and of monomode fibres 5 to 10 microns, depending on operating requirements and/or availability. A resolution of 200 microns is possible but this could be less, for example 10 to 50 microns or possibly even 5 microns.

Gauges can be compact in size (particularly embodiments as illustrated in Figure 4) and can

be made without bending the optic fibres, for example as in the in-line arrangement of Figure 1.

Claims

1. A displacement measuring gauge
- 5 comprising light transmitting means, a plurality of fibre optic light receiving paths, and encoder means operable to convert light passing from the light transmitting means to the fibre optic light receiving paths whereby relative movement
- 10 between said light and said encoder means results in a conversion corresponding to displacement being measured.
2. A gauge as claimed in Claim 1, wherein the light transmitting means comprise a plurality of
- 15 fibre optic paths disposed in substantial alignment with the fibre optic light receiving paths, the encoder means being disposed between the two paths.
3. A gauge as claimed in Claim 1, wherein the
- 20 light transmitting means comprise at least one fibre optic path disposed substantially parallel to the fibre optic light receiving paths, the encoder means being disposed between the two paths, means being provided to reflect light from the
- 25 light transmitting path to the light receiving paths.
4. A gauge as claimed in Claim 3, wherein the end faces of the fibre optic light receiving paths are disposed at 45° to their longitudinal axes.
5. A gauge as claimed in Claim 3 or 4, wherein
- 30 the light transmitting means comprises a slab waveguide having an end face disposed at 45° to the longitudinal axis of the waveguide.
6. A gauge as claimed in any one of Claims 1 to 5, wherein the encoder means makes use of a
- 35 Gray code.
7. A gauge as claimed in any preceding claim, wherein the receiving paths are operatively connected to a computer or microprocessor.
8. A displacement measuring gauge
- 40 comprising light path means, light source means for transmitting light signals along the light path means, light receiving means for accepting light signals coming from the light path means, encoder means operable to reflect light passing
- 45 from the light path means and back into said light path means whereby relative movement between the light path means and the encoder means results in a conversion corresponding to displacement being measured, the light path means and the encoder means being disposed in substantially parallel planes.
9. A gauge as claimed in Claim 8, wherein the light path means comprise a plurality of fibre optic paths.
- 55 10. A gauge as claimed in Claim 9, wherein the end faces of the fibre optic light receiving paths are disposed at 45° to their longitudinal axes.
11. A gauge as claimed in Claim 8, wherein the light path means comprise a slab waveguide
- 60 having an end face disposed at 45° to the longitudinal axis of the waveguide.
12. A gauge as claimed in any one of Claims 8 to 11, wherein the encoder means makes use of a Gray code.
- 65 13. A gauge as claimed in any one of Claims 8 to 12, wherein the light receiving means are operatively connected to a computer or microprocessor.
14. A displacement measuring gauge
- 70 substantially as hereinbefore described with reference to Figure 1 of the accompanying drawings.
15. A displacement measuring gauge substantially as hereinbefore described with
- 75 reference to Figures 3, 4 and 5 of the accompanying drawings.
16. A displacement measuring gauge substantially as hereinbefore described with reference to Figures 6 and 7 of the accompanying
- 80 drawings.
17. A displacement measuring gauge substantially as hereinbefore described with reference to Figure 8 of the accompanying drawings.